Supplemental Material

Title: Heatwaves in the United States: Mortality risk during heatwaves and effect modification by heatwave characteristics in 43 U.S. communities

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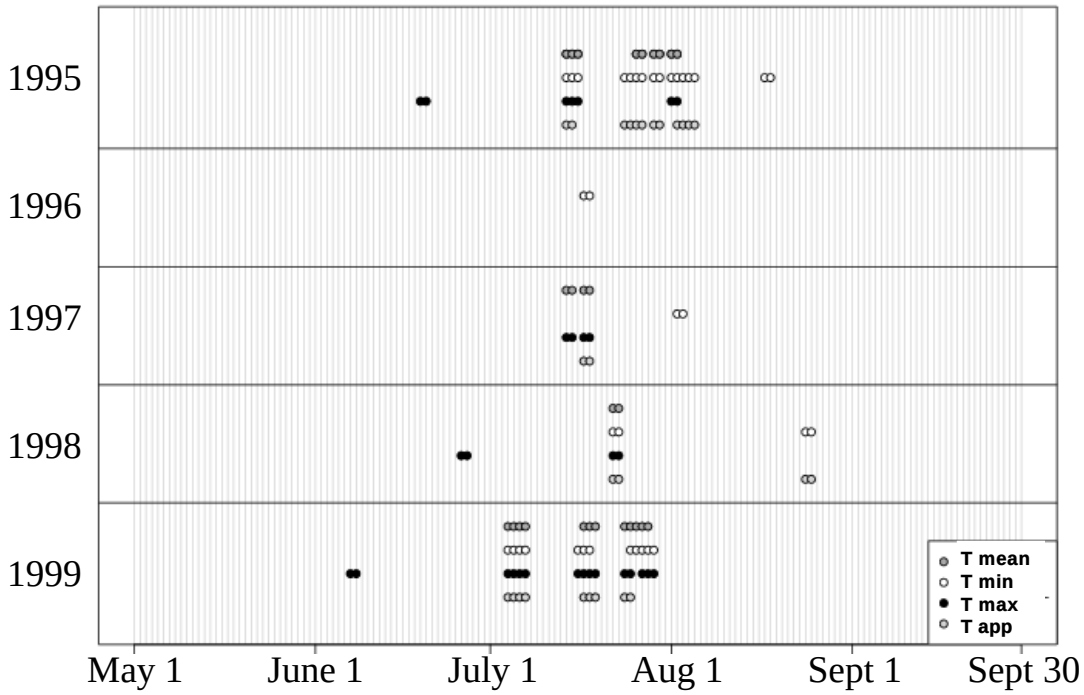
Table of contents

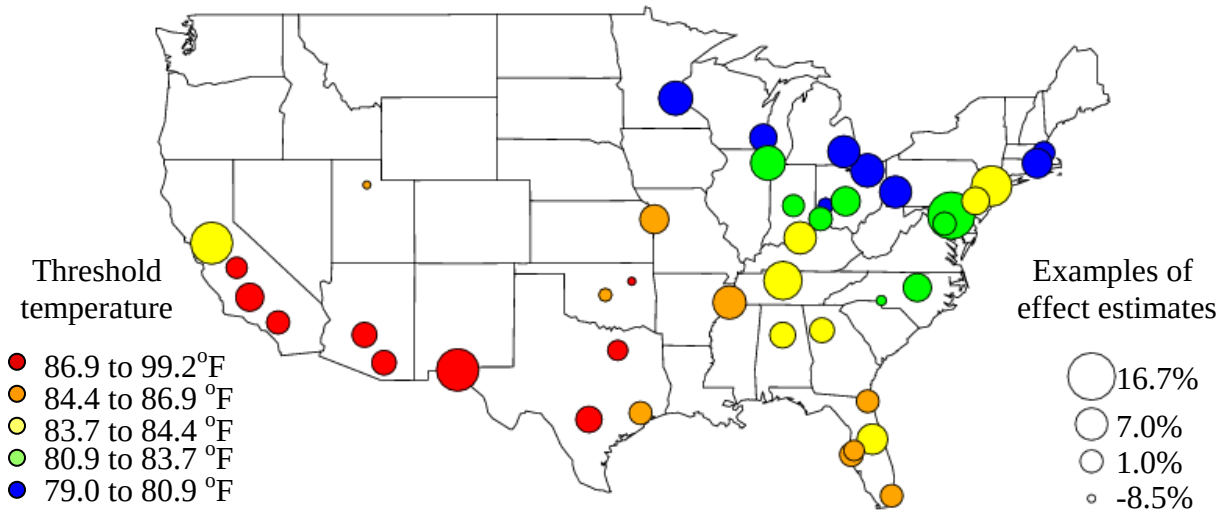
Figures

Tables



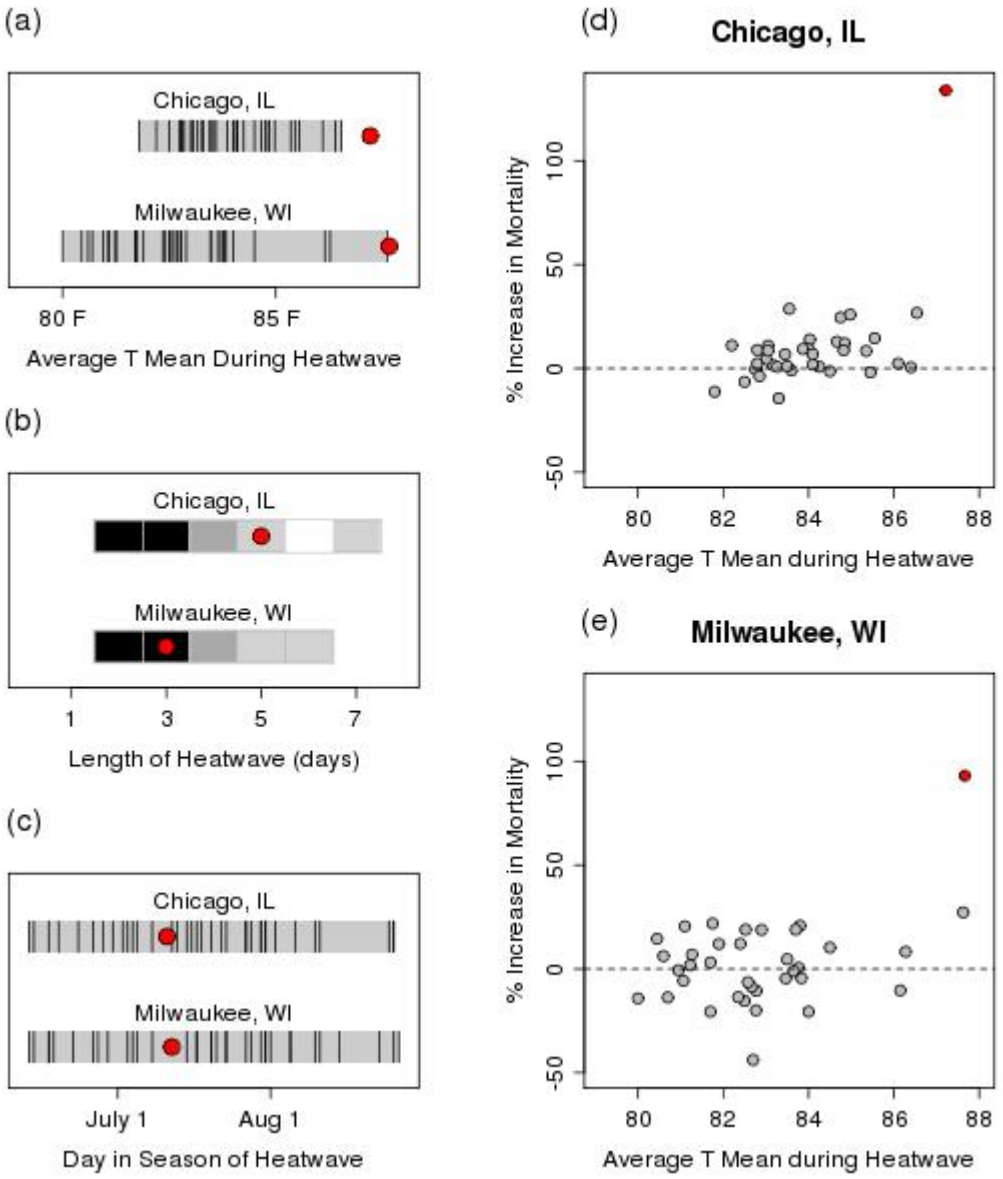
Supplemental Material, Figure 1. Illustration of how using different heatwave metrics to define heatwaves results in different heatwave periods.

Note: This figure shows five summers for New York, NY (1995-1999). For each date, a circle indicates that the day is in a heatwave using a heatwave definition based on the temperature metric indicated by the color of the circle. Heatwaves were defined as two or more consecutive days when daily values of the specified temperature metric (T_{mean}, T_{min}, T_{max}, or T_{app}) equaled or exceeded the 95th percentile of summertime temperature for that temperature metric.



Supplemental Material, Figure 2. Map of communities, their threshold temperature used to define heatwaves, and heatwave effects (*n*=43).

Note: Within each community, heatwaves were defined using a community-specific temperature threshold; these community-specific thresholds (95th percentile of warm season daily T_{mean}) is shown here by color. The overall community heatwave effect (risk of non-accidental mortality on heatwave days compared to non-heatwave days, adjusting for daily temperature [*added heatwave effect*]) is proportional to circle size. Analysis was for 1987 through 2005.



Supplemental Material, Figure 3. How the Chicago 1995 and Milwaukee 1995 heatwaves compare to other Chicago and Milwaukee heatwaves in terms of (a,d,e) intensity; (b) duration; and (c) timing in summer.

Note: In graphs (a) and (c), the gray bar shows the range of intensity or timing of all other heatwaves in the community, with black bars showing each individual heatwave. The red dots show the values of the 1995 heatwaves. In graph (b), the distribution of heatwaves by duration is shown by the color of the bars (black = 10 or more heatwaves; dark gray = 5 to 9; light gray = 1 to 4 heatwave; and white = no heatwaves), with the duration of the 1995 heatwaves shown with red dots. Graphs (d) and (e) show the association between the intensity and effects of all other heatwaves (each shown in gray) compared to the 1995 heatwave (shown in red). Heatwave effects were estimated as the percent increase in non-accidental mortality risk on heatwave days compared to non-heatwave days, adjusting for daily temperature (the *added heatwave effect* described by Hajat and coauthors [Hajat et al., 2006]).

Supplemental Material, Table 1. Communities included in analysis.
Note: The given communities are the 43 communities used in the main analysis of this paper. They are mapped in Supplemental Figure 2.

Communities		
Atlanta, GA	Houston, TX	Phoenix, AZ
Bakersfield, CA	Indianapolis, IN	Pittsburgh, PA
Baltimore, MD	Jacksonville, FL	Providence, RI
Birmingham, AL	Kansas City, MO	Raleigh, NC
Boston, MA	Louisville, KY	Salt Lake City, UT
Charlotte, NC	Memphis, TN	San Antonio, TX
Chicago, IL	Miami, FL	San Bernardino, CA
Cincinnati, OH	Milwaukee, WI	Stockton, CA
Cleveland, OH	Minneapolis/St. Paul, MN	St. Petersburg, FL
Columbus, OH	Nashville, TN	Tampa, FL
Dayton, OH	Newark, NJ	Tucson, AZ
Detroit, MI	New York, NY	Tulsa, OK
Dallas/Fort Worth, TX	Oklahoma City, OK	Washington, DC
El Paso, TX	Orlando, FL	
Fresno, CA	Philadelphia, PA	

Supplemental Material, Table 2. Metrics used to define heatwave intensity.
Note: This table shows the different definitions of *heatwave intensity* tested in sensitivity analysis.

Heatwave intensity metric	Definition
Average T_{max}	**Average** of daily **maximum** temperature for all days in the heatwave
Peak T_{max}	**Highest** daily **maximum** temperature attained during the heatwave
Average T_{min}	**Average** of daily **minimum** temperature for all days in the heatwave
Peak T_{min}	**Highest** daily **minimum** temperature attained during the heatwave
Average T_{mean}	**Average** of the daily **mean** temperature for all days in the heatwave
Peak T_{mean}	**Highest** daily **mean** temperature attained during the heatwave
Average T_{app}	**Average** of daily mean **apparent** temperature for all days in the heatwave
Peak T_{app}	**Highest** daily mean **apparent** temperature attained during the heatwave

Supplemental Material, Table 3. Example of heatwave identification and characterization for New York, NY (1987-2005).

Note: Heatwaves were identified as two or more days with $T_{mean} \geq$ the 95th percentile warm season T_{mean} for New York, NY. *Intensity* measures average T_{mean} during the heatwave. *Timing in summer* gives the date the heatwave started. *First in season* identifies if a heatwave was the first to occur in its summer.

Heatwave	Intensity (^{o}F)	Duration (days)	Timing in summer	First in season
July 10-11, 1987	82.3	2	July 10	yes
August 11-16, 1988	84.0	6	August 11	yes
August 4-6, 1989	83.7	3	August 4	yes
July 19-20, 1990	83.2	2	July 19	yes
July 18-21, 1991	86.0	4	July 18	yes
July 8-13, 1993	86.6	6	July 8	yes
August 3-4, 1993	82.8	2	August 3	no
July 14-16, 1995	85.6	3	July 14	yes
July 26-27, 1995	83.4	2	July 26	no
July 29-30, 1995	84.3	2	July 29	no
August 1-2, 1995	83.5	2	August 1	no
July 14-15, 1997	84.0	2	July 14	yes
July 17-18, 1997	83.3	2	July 17	no
July 22-23, 1998	84.8	2	July 22	yes
July 4-7, 1999	88.3	4	July 4	yes
July 17-19, 1999	83.3	3	July 17	no
July 24-28, 1999	83.7	5	July 24	no
August 8-9, 2000	82.5	2	August 8	yes
June 27-28, 2001	83.2	2	June 27	yes
August 7-10, 2001	87.2	4	August 7	no
July 2-5, 2002	85.7	4	July 2	yes
July 29-August 2, 2002	85.0	5	July 29	no
August 4-5, 2002	82.6	2	August 4	no
August 13-14, 2002	82.7	2	August 13	no
August 17-19, 2002	83.3	3	August 17	no
June 25-27, 2003	84.0	3	June 25	yes
July 5-6, 2003	84.4	2	July 5	no
August 14-15, 2003	82.6	2	August 14	no
July 19-22, 2005	83.7	4	July 19	yes
July 26-27, 2005	83.6	2	July 26	no
August 3-5, 2005	83.9	3	August 3	no
August 11-14, 2005	84.2	4	August 11	no
August 21-22, 2005	82.4	2	August 21	no

Supplement Material, Table 4. Median, minimum, and maximum of community-specific correlations between heatwave characteristics (*n*=43).

Note: For this table, we calculated the community-specific correlation between heatwave characteristics in each community. This table shows the median of these community-specific correlations. Also shown (in parentheses) are the minimum and maximum community-specific correlations. For example, the lowest correlation between *duration* and *day in season* in any community was -0.38, the highest correlation in any community was 0.24, and the median value for all community0specific values was -0.05.

	Day in season	Intensity (Average T_{mean})
Duration (days)	-0.05 (min: -0.38; max: 0.24)	0.33 (min: -0.03; max: 0.72)
Day in season		-0.09 (min: -0.46; max: 0.25)

Supplemental Material, Table 5. Sensitivity analysis of how changing the heatwave definition affects mortality effect estimates.

Note: Here we show main results using alternate heatwave definitions based on duration, intensity, temperature metric, or lag time. National average estimates are shown (n=43). The original heatwave definition was: a period of two or more days with daily T_{mean} greater than or equal to the 95th percentile summertime T_{mean}.

	Original definition	***Alternate duration*** (original definition: ≥2 days)		***Alternate intensity*** (original definition: 95th percentile)			***Alternate temperature metric*** (original definition: T_{mean})			***Alternate lag*** (original definition: lag0)
	≥2 days of 95th percentile or higher T_{mean}	**≥3 days** of 95th percentile or higher T_{mean}	**≥4 days** of 95th percentile or higher T_{mean}	≥2 days of **90th percentile** or higher T_{mean}	Two or more days of **98th percentile** or higher T_{mean}	≥2 days of **99th percentile** or higher T_{mean}	≥2 days of 95th percentile or higher **T_{min}**	≥2 days of 95th percentile or higher **T_{max}**	≥2 days of 95th percentile or higher **T_{app}**	≥2 days of 95th percentile or higher T_{mean}, **one day lag (L1)**
Average heatwave characteristics # of heatwaves/year	**1.9/year**	1.0/year	0.6/year	3.5/year	0.8/year	0.4/year	1.9/year	2.5/year	1.8/year	1.9/year
Average heatwave intensity	**86.4 ^{o}F**	86.8 ^{o}F	87.1 ^{o}F	84.9 ^{o}F	88.0 ^{o}F	89.0 ^{o}F	84.9 ^{o}F	84.7 ^{o}F	86.1 ^{o}F	86.4 ^{o}F
Average heatwave duration	**3.3 days**	4.4 days	5.4 days	3.7 days	2.9 days	2.7 days	3.2 days	3.4 days	3.2 days	3.3 days
Average heatwave day in season	**July 21**	July 20	July 20	July 20	July 20	July 20	July 23	July 21	July 22	July 21
Average heatwave effect (95% P.I.)	**3.74% (2.29%, 5.22%)**	4.37% (2.70%, 6.06%)	4.24% (1.79%, 6.75%)	3.08% (2.04%, 4.14%)	5.40% (3.37%, 7.47%)	6.17% (2.60%, 9.87%)	3.00% (2.00%, 4.01%)	1.84% (0.84%, 2.85%)	4.25% (3.08%, 5.43%)	2.71% (1.34%, 4.10%)

Importance of heatwave characteristics Heatwave intensity[a]	**2.49%*** **	1.94%**	0.51%	1.51%***	3.89%***	8.18%***	1.12%***	1.22%***	1.64%***	2.41%***
Heatwave duration[b]	**0.38%**	0.19%	0.41%	0.05%	0.65%	1.54%	0.03%	0.27%	0.60**	0.61%**
Heatwave day in season[c]	**-0.06%** **	0.21%	0.03%	-0.02%	-0.06%	-0.02%	-0.07%**	-0.03%	-0.07%**	-0.06%**
First versus later heatwaves % of heatwaves that are first in their summer	**39%**	28%	38%	26%	60%	75%	40%	31%	41%	40%
Average effect of first heatwaves in summer (95% P.I.)[d]	**5.05% (3.06%, 7.06%)**	3.48% (-0.43%, 7.55%)	5.91% (0.90%, 11.16%)	3.33% (1.82%, 4.86%)	5.70% (2.66%, 8.83%)	----[e]	3.87% (2.08%, 5.69%)	1.96% (0.24%, 3.70%)	5.16% (3.25%, 7.10%)	3.26% (1.09%, 5.46%)
Average effect of later heatwaves in summer (95% P.I.)[d]	**2.65% (1.14%, 4.18%)**	4.55% (2.62%, 6.51%)	3.60% (0.34%, 6.96%)	2.87% (1.88%, 3.87%)	4.28% (0.93%, 7.74%)	----[e]	2.34% (1.05%, 3.65%)	1.53% (0.28%, 2.81%)	3.47% (2.01%, 4.94%)	1.87% (0.50%, 3.27%)

Statistical significance is noted as * p > 0.10, ** p > 0.05, and *** p > 0.01.

Note: T_{mean} is the daily mean temperature.

[a]Percent increase in relative risk during a heatwave compared to non-heatwave days for a 1 ^{o}F increase in average T_{mean}.

[b]Percent increase in relative risk during a heatwave compared to non-heatwave days for a one day increase in heatwave duration.

[c]Percent increase in relative risk during a heatwave compared to non-heatwave days for a one day increase in day in season.

[d]Percent increase in mortality risk during a heatwave compared to non-heatwave days.

[e]There were not enough communities with heatwaves later in the season to calculate all estimates under this heatwave definition.

Supplemental Material, Table 6. Median of community-specific correlations between metrics of heatwave intensity. (n = 43).

Note: "Peak" is the highest daily value attained during the heatwave for the specified metric; "average" is the average of all daily values during the heatwave for the specified metric.

Measure of heatwave intensity		**T_{max}**		**T_{min}**		**T_{mean}**		**T_{app}**	
		Peak	***Average***	***Peak***	***Average***	***Peak***	***Average***	***Peak***	***Average***
T_{max}	***Peak***	1.00							
	Average	0.93	1.00						
T_{min}	***Peak***	0.03	-0.11	1.00					
	Average	-0.18	-0.32	0.87	1.00				
T_{mean}	***Peak***	0.73	0.64	0.46	0.22	1.00			
	Average	0.70	0.67	0.40	0.21	0.93	1.00		
T_{app}	***Peak***	0.43	0.27	0.59	0.48	0.76	0.69	1.00	
	Average	0.25	0.19	0.56	0.56	0.59	0.67	0.92	1.00

Supplemental Material, Table 7. Percent increase in relative risk of mortality during heatwave for a 1 ^{o}F increase in the heatwave intensity metric.

Note: "Peak" is the highest daily value attained during the heatwave for the specified metric; "average" is the average of all daily values during the heatwave for the specified metric.

Metric		**National (n=43)**	Northeast (n=7)	Midwest (n=12)	South (n=19)
T_{max}	Peak	**0.51%****	0.81%	1.82%***	-0.06%
	Average	**0.50%****	0.71%	1.04%**	-0.12%
T_{min}	Peak	**0.61%****	1.85%***	0.61%	-0.06%
	Average	**0.50%***	1.98%**	0.28%	-0.01%
T_{mean}	Peak	**1.50%*****	2.86%***	2.07%***	0.03%
	Average	**2.49%*****	4.38%***	3.21%***	0.43%
T_{app}	Peak	**0.75%*****	1.66%***	0.83%*	0.19%
	Average	**0.89%****	2.34%***	1.01%	0.24%

Statistical significance is noted as * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

References

Hajat S, Armstrong B, Baccini M, Biggeri A, Bisanti L, Russo A et al. 2006. Impact of high temperatures on mortality: Is there an added heat wave effect? Epidemiology 17(6):632-638.